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Stochastic Frontier Approach to Resource-Use Efficiency Analysis of Cotton farmers In Northeast Zone, Nigeria

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Abstract— **The paper examined the Stochastic Frontier Approach to Resource-Use Efficiency Analysis of Cotton Farmers in Northeast Zone, Nigeria. Data were obtained from a sample of 360 households using a structured questionnaire. Descriptive Statistics and resource-use efficiency models were employed in analyzing the data collected. Results show that the mean year of cotton farmers in the study area was almost 49, with 12.53 as a Standard deviation. More than half of the cotton farmers did not acquire a higher level of education. The result shows that cotton farmers have various experiences in their farming activities with a mean farming experience of 17.48 and a Standard Deviation of 6.23. This ascertained the fact that "experience boosts professional disposition in the art of carrying out farming activities". The input/output variation result shows that the coefficient of variation of production is 192.54 kg/ha, indicating a larger variability in cotton production among farmers. Fertilizer had the meanest variability of 89.10 kg/ha and Standard deviation of 25.75 with a minimum and maximum quantity of 20 kg/ha, and 200 kg/ha, respectively. The result of the resource-use efficiency shows that the labor coefficient is negative, meaning that farmers are experiencing a decrease in their profit as a result of extreme use of labor. The variable inputs as seed, fertilizer, and agrochemical are being utilized efficiently by the farmers in the study area, as their coefficients are greater than one. Therefore, the research concludes that for the output to be increased, variables with a positive coefficient greater than one should be increased.**

Index Terms— **Cotton, Stochastic, Resource-use, Efficiency, Agrochemical, Experience.**

I. Introduction

Cotton is one of the main sectors that is significant because it plays an important part in the economic development of Nigeria. Cotton contributes to the Nigerian Gross Domestic Product (GDP) and creates jobs for many citizens and improves farmers' incomes in the country. The sector was one of the major industrial parts that the country had serious pride in as its influence pervaded the whole of Africa and beyond, both in terms of employment generation and contribution to national GDP (National Bureau of Statistics, 2015) **[1]**. The cotton trend in Nigeria, that is from 1979 to 2018, shows that area planted, yield, and cotton production have been declining. From Table 1, we can see that apart from 1991, in which Nigeria cultivated the highest number of hectares (430,000), the country experienced a decline in the area under cultivation. This hurts cotton yield as well as the volume of cotton production. Despite a 10% increase in cultivated area in 2018, this had no effect on cotton yield when compared to the production output in 2015.In general, from 1979 to 2018, the situation of the area under cultivation, yield, and cotton productivity has been in flux in the country. Notwithstanding, there is fluctuation, as earlier stated and discussed, but some of the time it comes with an increase in productivity, as in 1997, 2000, and 2018. The increase in these years' productivity led to higher cotton yields, as their production levels showed an increasing trend over time. This may be attributed to the action taken by the government that led to an increase in cotton yield when compared with the area planted in the trend, USADA, 2022,[2]

Table.1: Area Planted, Yield, and Total Production in Nigeria 1988-2021

Year	Area (ha)	Yield (Kg/ha)	Production (Kg)
1988	370	114	41,978
1991	430	140	60,030
1994	210	310	60,683
1997	350	200	70,035
2000	350	249	87,000
2003	380	241	90,263
2006	380	229	87,000
2009	395	248	97,875
2012	300	236	70,688
2015	260	193	50,025
2018	270	190	51,113
2019	150	290	63,134
2020	270	350	76,202
2021	270	350	76,202

Source: (USDA, 2022)**[2]**

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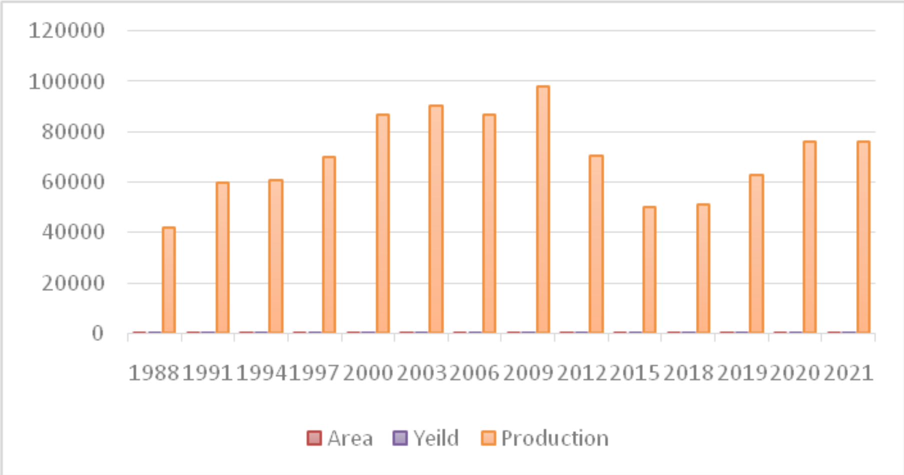

Figure.1: Planted area, average yield, and total production in Nigeria.
Source:(USDA, 2022)**[2]**

II. MATERIAL AND METHOD OF THE STUDY

A. Study Area

The study was conducted in the North-East Zone of Nigeria. The North East (NE) Geopolitical Zone of Nigeria covers close to one-third (280,419km^2) of Nigeria's total land area of (909,890km^2). It comprises six (6)States: Adamawa, Bauchi, Borno, Gombe, Taraba and Yobe. Three (3) States (Adamawa, Gombe, and Taraba State) were purposively selected for the study. In each state, concentration was given to areas where cotton production is a predominant occupation of the people in the area. In AdamawaState, the study was carried out in cotton-growing areas of Numan, Yola south, Lamure, Demsa, and Guyuk which constitute Zone three and four of Adamawa state Agricultural Development Project; hence four privately owned ginneries are located within the cotton belt. The presence of these companies has intensified cotton production in the area. Most cotton out-growers are registered with these private ginneries.

Similarly, in Gombe state cotton-growing belt, Gombe South and North, Akko, Billiri, and Kaltungo are the areas where cotton is being cultivated. In Taraba state, as in the other two states, the local governments where cotton is being cultivated are Lau, Gassol, and Karim Lamidoare cotton-producing areas, therefore, attention was given to them for this study. Three hundred and sixty (360) registered cotton out-growers were randomly selected with the assistance of extension officers of the private ginneries in the cotton belt of the study areas.These States have 13.5% (i.e., 23,558,674) of Nigeria's population which is put at 173,905,439, and have been a major contributor to national net food production, Abiayi, et al. [3].

B. Sampling Procedure

The target population for the study is the cotton farmers in the three states of the Northeast Zone: Adamawa, Gombe, and Taraba State. Adamawa state has twenty-two (22) local governments and five (5) were selected. Gombe State has eleven (11) local governments and three (3) were selected. On the other hand, Taraba State has sixteen (16) local governments and four (4) were selected.

Also, the list of the cotton farmers was obtained from the Afcott out-growers scheme. As a result, a two-stage simple random sampling (SRS) procedure was used to select local government and cotton farmers. A total of twelve (12) local governments were selected as the first stage for the study through a randomized sampling design out of forty-nine (49) local governments in the study area. At the final (second) stage, a total of 165 cotton farmers were selected out of 501 farmers in Adamawa state. In Gombe State, 102 cotton farmers were selected out of 520, while 93 cotton farmers were selected from Taraba State, out of 338 cotton farmers in the area. This gives a total of 360 sampled respondents out of 1359 cotton producers in the study area.

C. Sample Size

Yamane (1967) provides a simplified formula for computing the sample sizes. Following the formula for calculating sample size as proposed by Yamane (1967), the study arrived at its sample size based on the population of cotton farmers available in the study area during the study period. The Yamane formula is specified as follows:

$$n = \frac{N}{1+N(e^2)} \qquad \textbf{(1)}$$

Where n = sample size, N = population size and e = level of precision.

The total sample size of cotton farmers is determined as:
N = 4000, e = 0.05 (0.95 confidence interval). Therefore:
n = 4000/1+4000(0.05)^2
= 360 respondents in all.

The sample of the respondent in each state in the study area was determined as:
N= 1359, e = 0.05 (95% confidence interval). Therefore:
Adamawa sample size
n = 501/1359 x 360= 165 farmers
Gombe State sample size
n = 520/1359 x 360= 102 farmers
Taraba State sample size

n = 338/1359 x 360= 93 farmers

Data Collection The study relied heavily on primary data, which was gathered from a sample of 360 households using a structured questionnaire. The respondents also provided information on socioeconomic variables such as age, education, farming experience, extension contact, credit access, and off-farm activities.

Sampling Techniques The sampled states were Adamawa, Gombe, and Taraba State. Adamawa state has twenty-two local governments and five were selected. Gombe State has eleven local governments, and four were selected. The list of the cotton farmers was obtained from the Afcott out-growers scheme.A total of thirty-two local governments were selected at the first stage of the study through a randomized sampling design, out of sixteen local governments in the study area. At the final (second) stage, a total of 165 cotton farmers were selected out of a total of 2505 farmers in Adamawa state. While in Gombe State, 102 cotton farmers were selected out of 1560, and 93 cotton farmers were selected from Taraba State out of 1350 cotton farmers in the area. This gives a total of 360 sampled respondents out of 5465 cotton producers in the study area.

D. Data Analysis

The decision to select a functional form is very important to any empirical research because the selected functional form can significantly affect the parameter estimates, Kebede,2001.[4]. The most common functional forms of stochastic frontier models generally used are the Cobb-Douglas and Trans-log functional forms, as various studies have employed them in their analysis. Among the researchers that employed Cobb-Douglas in their work are (Khai and Yabe, 2011) **[5]**, (Ahmadu and Alufohai, 2012) **[6]**,and (Rahman et al., 2012) **[7]**. This functional form is very easy to adopt, but it imposes a severe restriction on production elasticity to be constant and the elasticity of input substitution to be unitary. The Trans-log functional form has been used by researchers such as Abdullah and Mushtaq (2007) [8], (Ogundari and Akinbogun, 2010) [9], Onumah, and Acquah (2010) [10], and (Donkoh, et al. 2013) [11]. The functional form is known to be less restrictive, permitting the combination of squared and cross-product terms of the exogenous variable inputs with the view of having the goodness of fit in the model.

Trans-log Production Function Specification. In this research, trans-log stochastic production function model was employed with flexible risk specification as presented below:

$$\boldsymbol{lnP_j = \alpha_0 + \sum_{i=1}^{4} \alpha_i lnx_i + 0.5\sum_{j=1}^{4} \alpha_{ii} lnx_i^2 + \sum_{i=1}^{4}\sum_{k=1}^{4} \alpha_{ik} lnx_i lnx_k + \varepsilon_j} \quad \textbf{(2)}$$

Where the stochastic disturbance term, ε_j, is presented as:

$$\boldsymbol{\varepsilon_j = g(x;\varphi)v_i - h(x;z)u_i} \quad \textbf{(3)}$$

$g(x;\varphi)v_i$ is the risk function component, $h(x;z)u_i$ is the technical inefficiency function component, P_j is the quantity of cotton produced by i-th farmer measured in kg/ha, x_i is the quantity of seed used measured in kg/ha, x_i is the quantity of fertilizer used measured in kg/ha, x_i is the quantity of agrochemicals used measured in lt/ha and x_i is the labour used measured in Man-days/ha, j is j-th farmer where j= 1,2,3…..360 and i is i-th input where i= 1,2,…,4 and α_0, α_1, α_{ii}, and α_{ik} are the estimated parameters of production technology.

The coefficients of the Trans-log Production Function are the marginal productivities of the corresponding inputs concerning output. To ensure maximum profit and efficiency, a farmer must utilize resources at a level where their marginal value product (MVP) is equal to their marginal factor cost (MFC) under perfect competition (Kabir et.al., 2006) [12]. The efficiency of a resource was determined by the ratio of MVP of inputs (based on the estimated regression coefficients) and the MFC. Following Goni et al. (2007) [13], Fasasi, 2006.[14] and Stephen et. al; (2004) [15], the efficiency of resources is given as;

$$r = \frac{MVP}{MFC} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where r = Efficiency coefficient MVP=Marginal Value Product and MFC=Marginal Factor Cost of inputs. $MFC = P_{xi}\ Where\ P_{xi} = Unit\ price\ of\ input\ X_i$. MVP is obtained from the expression, $MVP = MPPx\,P_y$ Where MPP= Marginal Physical Product and Py = Unit Price of Output.The MPP is obtained from the estimated coefficients of the Cob-Douglas production function which are the elasticities ofproduction (E).

$$MPP_x = \frac{\delta y}{\delta x} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

But

$$E = \frac{\delta y}{\delta x}.\frac{x}{y} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Therefore,

$$E_x.\frac{x}{y} = \frac{\delta y}{\delta x} = MPP_x \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

Also,

$$MPP_x = E_x.\frac{x}{y}.P_y \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

Where y = output mean value of y, x = input mean value of x.

The Marginal Value Product (MVP) for each input was obtained by multiplying the estimated coefficients of the Cob-Douglas production function of that input with the ratio of the mean value of output and that input and with the unit price of output. However, the marginal factor cost (MFC) of each input was obtained from data collected on the unit market prices of the various inputs during the 2006 production season.

The decision rule for the resource-use efficiency analysis is if r = 1; the resource is being used efficiently. r > 1 indicates that the resource is underutilized, and increased utilization will increase output. r<1; a resource is overutilized, and reducing its use would result in profit maximization.

E. Marginal Productivities and Resource-Use Efficiency

To determine the productivity of inputs, two factors should be considered: the quantity of inputs used in the production process and the level of the other resources combined. This shows that the estimates with the widest applicability are derived by using the geometric mean input level. Hence, the input's geometric mean was used in determining the VMPs, that is, value marginal products. In addition, the market prices that prevailed during the production season (2020–2021) were used in determining the geometric mean of input and output prices. The cost of renting land was taken as the market price of land. The equ-marginal principle states that a production input is being used efficiently if the ratio of the VMP of input to its unit price is equal to unity.

F. RESULTS AND DISCUSSIONS

Socio-economic characteristics of cotton farmers. The results and discussions of the various estimates of the study were presented. These includethe age, educational levels, and farming experience of the respondents.

The result shows that the greater number of the respondent had fallen within the age of 51-60 years while the small proportion of the respondent had less than 30 years of age. Although 20% of the respondent in the study areas had 61 years or more, the mean year of cotton farmers in the study area was almost 49, with a Standard deviationof 12.53,whereas 25 and 75 as the minimum and maximum years of farming respectively.

The resultdepicts that the cotton farmers in the study area are in their productive age. The result concords with the report of Onu and Edon, 2009[16] in their conducted farm survey, that there is a significant relationship between farmers' age and efficiency. In addition, they stated that farmers in their youthful age tend to produce more efficiently on the farm than the aged ones because the younger farmers are more ingenious and energetic to work on the farm. Idiong *et. al.,* (2007)[17] in their findings cited that 75% of the farmers in Cross River State were within their adulthood age and middle age with the possibility of high productivity in their farms. This determines the number of man-hours or man-days farmers could devote and spend when carrying out farm activities per day during the cropping season and production period. Accordingly, Alarm et al. (2013)[18] argued that the predominance of youthful people in cotton production could be because of the labor-intensive nature of its production, which requires younger and energetic farmers. The reason could be that younger farmers are more active, enthusiastic, energetic, and capable of making good production decisions with the potential for productivity, in the future, as they are likely to be more efficient in cotton production than the older farmers.

Age

Table2: Age distribution of cotton farmers

Age (Years)	Frequency	Percentage (%)
< 30	22	6.3
31-40	50	14.3
41-50	61	17.4
51-60	146	41.8
61 & above	70	20.2
Total	**349**	**100**
Mean	49	
Minimum	25	
Maximum	75	
Standard deviation	12.53	

Source: Field Survey data, 2020.

Educational Level

Table3shows that the majority (44%) of the cotton farmers had no formal education. Nevertheless, some (27%) and 19% of the respondent attended primary and secondary school in the study area with a negligible number (6.9% & 2%) pursuing further studies in the tertiary institutions. From the result, it is therefore clear that more than half of the cotton farmers were uneducated.

The acquirement of a higher level of education in one's life is a persuasive determinant of his capacity to produce goods and services in society as it enhances his ability to coordinate inputs in agricultural production. The level of education helps in increasing farmers' productivity, income, level of their savings, and investment in their agricultural production activities, which will boost their ability to raise their production frontier. Muhammad Lawan *et al.* (2009) [19] in their studies affirmed that level of education is expected to influence farmers' adoption of agricultural innovations and decisions on various aspects of farming. Therefore, they stand up for the opinion that education is a veritable attribute in supporting farmers to innovate, adapt and adopt improved seed and recommended production practices. Lockheed et al. (1979) in their studies affirmed that on average, the level of education increases farm productivity, by 7.4% as a result of a farmer's completing four years of elementary education rather than none; the 7.4% is a weighted average of value from those studies for which an estimate could be computed. The effects of education were much more likely to be positive in modernizing agricultural environments rather than in traditional ones, which we ascertained both by inspection and by regressing the measured effect of education on productivity against the modernization of the environment and other variables.

Table3: Distribution of Respondents by their Level of Education

Level of education	Frequency	Percentage (%)
No formal education	154	44.1
Primary school	96	27.5
Secondary school	68	19.5
NCE/Diploma	24	6.9
Degree & above	7	2.0
Total	**349**	**100**

Source: Field Survey data, 2020.

Experience

The result from Table 4 shows that most of the sampled farmers (41.5%) had experience between 20-24 years. Even though 28.7% of the respondent had experience between 15-20 years of cotton farming, 11.7% had experience between 10-14 and 8% of the respondent had farming experience between 5-9 years. In addition, there are 5.8% of the respondent with 25 & above farming experience, while 4.3% had less than five years of farming experience. The mean year of experience among cotton farmers was 17.48 years, with 6.23 Standard Deviation, while the minimum and maximum years of farming experience were 2 and 32 years respectively.

the result of this study shows that cotton farmers have various experiences in their farming activities. This is agreed with Odedokun (2015)[20] findings on the Economic Analysis of Cotton Production and Supply Trend Estimation in Zamfara State, Nigeria, in which he describes the experience as the process of gaining knowledge and skill in carrying out certain farm operations. This ascertained that it is undeniable fact “experience boosts professional disposition in the art of carrying out farming activities”. Likewise, the Number of years spent on production by a farmer demonstrated how competent, knowledgeable and skillful, gained by the farmer in the production enterprise. This agreed with the findings by Ajani (2000)[21],Resource productivity in food crop farming in Northern area of Oyo State, Nigeria where their study showed that year of farming experience may increase agricultural productivity among farming household in Nigeria.

Table4: Distribution of Respondents by Experience

Level of Experience	Frequency	Percentage (%)
< 5	15	4.3
5-9	28	8.0
10-14	41	11.7
15-19	100	28.7
20-24	145	41.5
25 & above	20	5.8
Total	**349**	**100**
Mean	17.48	
Minimum	2.00	
Maximum	32.00	
Standard Deviation	6.23	

Source: Field Survey data, 2020.

G. Output And Input Variables Results

The summary statistics for the generated variables from the survey are presented in Table 5. From this corollary, the average cotton production of the surveyed farms was 884.9 kg/ha, with a minimum and maximum production of 210 kg/ha and 1053 kg/ha, respectively. However, the coefficient of variation of production is 192.54 kg/ha, meaning that there is a larger variability in cotton production among the sampled farmers. Fertilizer was also the input used that had the most variability among the surveyed farmers. Fertilizer has meant a minimum and maximum quantity of 89.10 kg/ha, 20 kg/ha, and 200 kg/ha, respectively, with a coefficient of variation of 25.75 kg/ha, indicating that there is a large variability in its use among the surveyed farms. Nonetheless, a variation in inputs could be the result of farmers' buying an additional quantity apart from the subsidy given to them. The quantity of seed used, on average, was 39.23 kg/ha, with a minimum and maximum quantity of 8 kg/ha and 60 kg/ha, respectively. On the other hand, the coefficient of variation of seed used among the sampled farms was not large (9.79 kg/ha) compared to fertilizer and labour. In all, agrochemicals had the least coefficient of variation (3.35 Lt/ha), proving that the variability among the sampled farmers with regards to the quantity of agrochemicals used is not large.

Table 5: Summary Statistic of input and output variables for the mean

Variable	Unit	Mean	Min	Max	Std Dev.
Output					
Cotton	Kg/ha	884.90	210	1053	92.54
Inputs					
Seed	Kg/ha	39.23	8	60	9.79
Fertilizer	Kg/ha	89.10	20	200	25.75
Agrochemicals	Lt/ha	5.02	2	28	3.35
Labour	Man-day/ha	52.50	20	81.6	16.6

Source: Field Survey data, 2020.

H. Resource-useEfficiency in cotton Production

Table 6shows the result of the resource-use efficiency of the cotton farmers in the Study area. From the result estimation, we can see that the labour coefficient is negative, indicating that farmers'extreme use of labour which the end, resulting in a decrease in their profit. On the other hand, the variable inputs such as seed, fertilizer, and agrochemical are being utilized efficiently by the farmers in the study area, as their coefficients are greater than one. For the output to be increased these variables with positive coefficients and greater than one should be increased.

Table 6:Resource-use Efficiency in cotton Production of respondents

Resource/Input	Coefficient	MVP	MFC	r
lnseed	0.2789	197.25	10.5	18.79
lnfert	0.2753	70.03	8	8.75
lnchem	0.2046	55.75	13	4.29
lnlabour	-0.2558	-45.30	7	-6.47

Source: Field Survey data 2020.

III. CONCLUSION

Cotton farmers, according to the results of this study, had hit their peak productivity. This signifies that perhaps the age of a farmer and his or her efficiency are linked. Furthermore, the figures revealed that owing to their resourcefulness and enthusiasm for agricultural labour, the majority of the farmers produce more goods on the farm than aged farmers.

According to the findings, more than half of cotton growers lack higher education. Higher education enhances one's ability to coordinate agricultural inputs, making it a powerful determinant of one's ability to generate goods or services in society. Educational attainment benefits farmers' productivity, revenue, savings, and investment in farm production activities, all of which increase their potential to expand their production frontier. According to the findings of this study, most cotton farmers have varying levels of experience in their farming activities.

According to the summary of variables, the average cotton production was 884.9 kg/ha, with a coefficient of variation of production of 192.54 kg/ha. This indicates that there is more variation in cotton production among the farmers sampled. Fertilizer has a coefficient of variation of 25.75 kg/ha, showing that its application varies greatly among the farms assessed. However, a difference in inputs could be the consequence of farmers purchasing an additional quantity in addition to the subsidy. In contrast to fertilizer and labor, the coefficient of variation of seed utilized across the investigated farms was not large (9.79 kg/ha). Overall, agrochemicals showed the lowest coefficient of variation (3.35 Lt/ha), demonstrating that there is a little variation amongst them.

The coefficients of the variable inputs, except labor, which has a negative sign, are all positive, according to the estimated parameters of the stochastic frontier production function. The positive sign of these coefficients signifies that they have a positive relationship with output, implying that increasing them will raise output levels. However, in the case of labor, it indicates a negative contribution to output, i.e., more labor yields less output.

Cotton farmers in the study area's resource-use efficiency. The result estimation shows that the labor coefficient is negative, indicating farmers' excessive use of labour, which, in the end, results in a decrease in their profit. Farmers in the study area are actively utilizing variable inputs such as seed, fertilizer, and agrochemicals, as their coefficients are greater than one. Variables with efficiency encompassing and greater above one should be increased to increase output.

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